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Article

'Medicorobots' As an Emerging Biopower: How COVID-19 Has Accelerated Artificial Intelligence in A Post Corona-World

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Abstract

The novel pathogen Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the cause of coronavirus disease (COVID-19), has created a global crisis. Currently, the limits of public health systems and medical knowhow have been exposed. COVID-19 has challenged our best minds, forcing them to return to the drawing board. Fear of infection leading to possible life-long morbidity or death has embedded itself in the collective imagination leading to both altruistic and maladaptive behaviours. Although, COVID-19 has been a global concern, its advent is a defining moment for artificial intelligence. Medicorobots have been increasingly used in hospitals during the last twenty years. Their various applications have included logistic support, feeding, nursing support and surface disinfection. In this article we examine how COVID-19 is reframing technology/human interactions via medicorobots, and the future implications of this relationship. In the last section we predict possible developments in artificial intelligence and how they may benefit future humanity in medicine.

Keywords

Embodiment, ON-WORLD, IN-WORLD, Global, Biopower, Future, Artificial Intelligence

Introduction

The novel pathogen Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), the cause of coronavirus disease (COVID-19), has created a global crisis. Currently, the limits of public health systems and medical knowhow have been exposed. In short, SARS-CoV-2 has challenged our best minds, forcing them to return to the drawing board. Fear of infection leading to possible life-long morbidity or death has embedded itself in the collective imagination leading to both altruistic and maladaptive behaviours. Although, COVID-19 has been a global concern, its advent is a defining moment for artificial intelligence. Twentieth century history shows that global crises have been catalysts for technological developments. Similarly, this paper predicts that the current pandemic will accelerate the use of medical robots (medicorobots) and other forms of artificial intelligence across the spectrum of human societies. Global coronaphobia is facilitating present and future robotics. Medicine, as we know it will never be the same again.

In this article we examine how COVID-19 is reframing technology/human interactions via medicorobots, and the future implications of this relationship. In the last section we predict possible developments in artificial intelligence and how they may benefit future humanity in medicine.

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Theoretical Framework: Crossing Boundaries and Embodiment

Any relevant discussion of artificial intelligence should include Donna Haraway's notion of cyborgs (Haraway, 1991). For Haraway, the term 'cyborg' has a double meaning; firstly, as a metaphor of interaction between technology and the human body; second, as a social reality or science fiction. Haraway focuses her theoretical insight into human/machine embodiment – how technology extends the capacities of the human body. Technology does not only inform human cognition and abilities, but can potentialise the biological body.

Secondly, Haraway notes that extant humans are chimeric in nature, in that our lives have melded with technology to such a degree as to make it impossible to be separated from it, and function as a 'normal' human. Machine and human share a synergistic relationship, a common kinship that is now entering a new phase – a mechanomorphosis, that has been accelerated by the COVID-19 pandemic, as will be discussed later on.

The nascent humanization of robots which we have been witnessing during the last decade has increased our awe and ambivalence towards them as they now exist at the juncture between the "physical and non-physical" (Haraway, 1991, p. 152). These medicorobots, borne out of the exigencies of the COVID-19 pandemic, are further cyborgising human spaces (Luke, 1997, p. 1371), such as hospital environments.

Another important analysis that is relevant here is based on Maturana and Varela's (1980) thesis on living and technological systems, referred to as autopoiesis and allopoiesis, respectively. Autopoietic systems are mind systems, in that they exist within an interactive and interconnected network with other organisms (Bateson, 1973). Autopoietic systems are self-reproducing and adapt to their environments at both environmental and cellular levels. In contrast, allopoietic systems are not yet capable of self-reproduction and are only capable of adapting at a behavioural level. Although robots cannot reproduce in the way as autopoietic systems can, they can be programed to emulate the behaviors of their creators. In this sense, there is behavioral reproduction. Duffy and Joue (2000), claim that in allopoietic systems the mechanisms of production delineate the machine as a unity.

The ability for robots to adapt to and to interact with their environments is highlighted in the "ON-WORLD" versus "IN-WORLD" types of model as discussed by Duffy and Joue (2000). According to these authors, a major distinction between the two models is posited on the level in which artificial intelligence (AI) learns to adapt in different environments. We can elaborate here in relation to the distinction between a controller with their mechanism (AI's affect "ON its environment") versus a mechanical agent embedded in its environment (AI's influence "IN its environment") (Duffy & Joue, 2000). The former resembles an allopoietic system while the latter corresponds with an autopoietic system (Duffy & Joue, 2000). To further elaborate, the ON-WORLD model correlates to a robot's effect on its environment – the classical AI approach. Alternatively, the IN-WORLD model focuses on a robot's interaction within the environment in real time (Duffy & Joue, 2000). Thus, The IN-WORLD model provides a robot with various levels of mobility and flexibility so it can "interact and influence its environment" (Duffy & Joue, 2000).

> This integration of the agent into the environment allows greater real world autonomy; otherwise it is merely situated in its internal static representation of the real world, and as such is inherently flawed. (Duffy & Joue, 2000)

The IN-WORLD model finds similarity with behavior based approaches to artificial intelligence that began in the 1980's, that focus on robotic embedment and interaction within the environment (Brooks, 1986a, 1986b). Consequently, the IN-WORLD model is relevant to this analysis due to the interactive nature of COVID-19 inspired medicorobots.

The Rise of Medicorobotics

Medicorobots have been increasingly used in hospitals during the last twenty years. Their various applications have included logistic support, feeding, nursing support and surface disinfection (Dahl & Kamel, 2014). In the latter, disinfecting robots send ultraviolet (UV) light which can destroy pathogens, including coronaviruses from inanimate surfaces. This function reduces risk of inter-person contamination and enables for more optimal disinfection capabilities than when performed by humans (Yang, Nelson, Murphy, Choset, & Christensen, 2020). These disinfecting medicorobots are remotely controlled by a health care worker. Hospital robots such as TUG and

HelpMate transport supplies to nursing staff (Evans, 1994; Bloss, 2011; Chen & Kemp, 2011). The afore mentioned medicorobots consist of sensory assemblages that enable autonomous navigation and obstacle avoidance in hospital settings (Dahl & Kamel, 2014). Other medicorobots such as RP-VITA and GiraffPlus are robotic devices consisting of mobile video conferencing and alarm system monitoring functions for enhanced detection of health status in patients (Sucher, et al., 2011; Frennert, Forsberg, & Östlund, 2013).

The recent Ebola epidemic in Africa prompted the White House Office of Science and Technology Policy and the National Science Foundation in further exploring medicorobot applications. Three major areas have been identified by these scientific bodies as needing further research and development. These are:

1. Clinical care – decontamination, telemedicine
2. Reconnaissance – assisting in voluntary monitored quarantining
3. Logistics – waste handling and contaminant eradication (Fig. 1)

On this theme, Oña, Garcia-Haro, Jardón, and Balaguer (2019) note that medicorobots may function in optimising medical diagnosis, surgery, support and rehabilitation. Robotic assistance includes bed transference, surveillance and human logistics. Rehabilitative medicorobots cover post-surgery care, as well as, various types of prosthetic and rehabilitation aids (Oña et al., 2019).

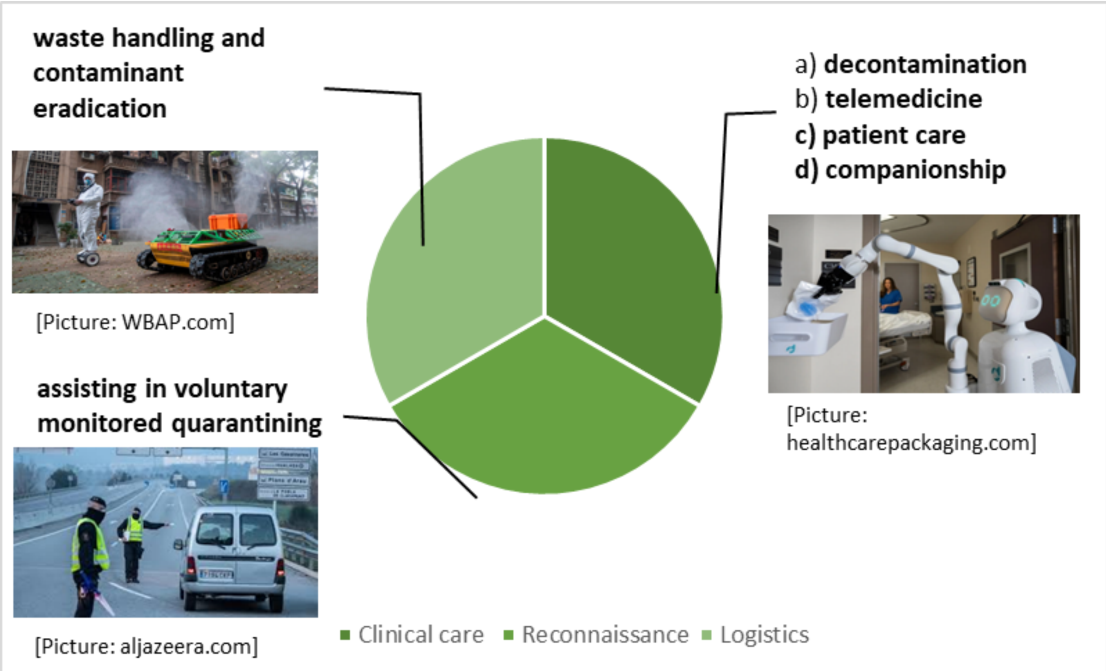

Fig. 1: Types of functions of medicorobots and non-medicorobots

A major concern of medicorobots has been patient safety. In relation to mobility, medicorobots are being designed to move safely and avoid collisions in hospital settings. Second, the surfaces of medicorobots can harbor viruses and bacteria. Consequently, medicorobots need regular disinfecting when in the presence of patients and health care workers. This is especially relevant to coronavirus family viruses which can stay on glass, plastic, wooden and metallic surfaces for days (Roderick & Carignan, 2007; Oña et al., 2019).

Medicorobots on the World Stage During COVID-19 Pandemic

By late 2019, a novel type of virus from the coronavirus family had emerged in Wuhan, China. The swiftness of the outbreak led to Wuhan being in quarantine. As more individuals succumbed to COVID-19 the hospitals filled, infecting healthcare workers and draining resources. This scenario was quickly copied in many other countries. During the early months of 2020 the use of medicorobots had accelerated at an unprecedented pace, firstly, in China and then Hong Kong. From 2015 to 2017, the use of robots in the Chinese health sector had increased by approximately 34% (GCiS, 2017).

With the advent of COVID-19 the Chinese quickly employed medicorobots and public robots to assist humans. The Chinese central government maintained an organized and efficient approach in early 2020 which reduced collective phobia of the then epidemic. There was comparatively little hoarding of items which has been evident in other countries.

In only a few months medicorobots have been successfully employed in many countries to combat COVID-19. This pandemic has been a crucible for testing the efficiency of medicorobots under extraordinary conditions. In early 2020 a field hospital was constructed in the Hongshan Sports Center in Wuhan. Dubbed the “Smart Field Hospital” it was a unique project facility utilizing robotic systems from companies CloudMinds and China Mobile. (Hornyak, 2020). The aim of the project was to relieve human care workers during the height of the pandemic. However, its use has been maintained even with a reduction in COVID-19 infections. In Smart Field Hospital medicorobots perform numerous medical and domestic tasks. Patients entering the hospital are monitored for their temperature by robotic systems, after which they are given bracelets that are synced with the CloudMinds artificial intelligence platform that measures their vital signs (Hornyak, 2020). Other robots provide patients with meals, drinks and entertainment such as dancing, while other medicorobots regularly disinfect the hospital environs. The entire hospital applies the IN-WORLD model of robotic embedment and engagement with humans.

Humanized Medicorobots as an Emerging Biopower

An interesting element of this pandemic has been a concern with humanizing medicorobots. For example, in Kerala, India, a humanoid female robot has been created during the pandemic which functions in distributing medicines. This medicorobot wears a yellow mask and displays on its chest area a diagram of hands being washed (Bhatia, 2020). An important element which we are witnessing in hospitals around the globe is the violation of the traditional doctor/patient relationship. Threatened by possible infection, the inner sanctum of doctor/patient relationship has been forfeited to machines. From the Foucauldian perspective, medicorobots have become embodiments of state control, given authority to discipline the diseased human body until it is well (Foucault, 2003).

Arguably, medicorobots can be considered as an emerging biopower, embodying the efficiency of the state and its promise to protect the populace. Their interactive and mobile humanoid forms have not only supplanted health care workers in many of their customary roles but from here onwards will be viewed more as virtuous agents providing life-saving services. The ‘savior’ role conferred on medicorobots by the world’s media is a case in point. As the global media is engaged in daily discourses of coronaphobia, creating a global fearscape, medicorobots are being viewed as reliable helpers to healthcare workers and the public (Murphy, Adams, & Gandudi, 2020). Medicorobots do not need to adhere to the rules of social distancing.

In keepingwith the saviour theme, many media photographs from Wuhan have depicted healthcare workers posing with CloudMinds medicorobots which are given center stage. (Fig. 2) These medicorobots have in a relatively short time achieved international stardom, pathing the way for the global acceleration of robotics in the post COVID-19 world.

Fig. 2: Healthcare professionals in a Wuhan hospital engaging in some frolic with the CloudMinds medicorobot. Such photographs showing positive interactions between of humans and medicorobots show how the latter is embedding How their bodies are observing a unity of intention. The robot takes center stage while they are all moving in dancelike sync. This level of interaction is synonymous with the IN-WORLD model. It also encapsulates Haraway's idea of the embodied interaction between human/machine. Source: CloudMinds

How Will Medicorobots Inform Human Futures?

COVID-19 is a unique global event that will generate sweeping changes to all socio-economic institutions. In relation to medicorobots we predict various future scenarios.

Increasing reliance and acceptance of medicorobots in all health care sectors

The COVID-19 pandemic has showcased the current capabilities of various kinds of medicorobots. Medicorobots are allopoietic systems constructed and programmed to perform repetitive tasks based on strict criteria. During the last decade they have been performing with increasing efficiency in many routine tasks, saving time and effort of health care personnel. We envisage that medicorobots in the future will be engineered for increasing meaningful social interaction with patients (Kidd, Taggart, & Turkle, 2006).

Firstly, the COVID-19 pandemic has been instrumental in providing a transformation of the collective imagination which no longer views robots as inimical or gimmicky as depicted in numerous movie and television genre. IN-WORLD based medicorobots have benefitted medical personnel and patients in performing vital tasks hospital tasks. Unless medicorobots develop a mechanical or software malfunction, they do not make errors. They are also indefatigable. Time and effort saved by medicorobots will eventually become appositely deployed by medical personnel for decision making that requires a choice among alternatives that includes exceptional characteristics of patients and their circumstances. Complex differential diagnoses that take into account specific comorbidities and treatment choices in patient care are a case in point. In short, patients will eventually learn to consider medicorobots the same as CT or MRI machines while precision and efficiency in patient care will increase. For an individual patient an interaction with medicorobots may initially evoke ambiguity. However, based on global media reports there has apparently been a high acceptance of medicorobots where ever they have been employed during the COVID-19 pandemic.

Ultimately, the correct functioning of any health service depends on sociopolitical circumstances and financial capabilities of each state. The use of medicorobots will assist in increasing efficiency of health services while freeing medical personnel to devote their attention to complex decision making rather than being tied to routine tasks. This will be a win-win situation for both medical staff and patients.

Secondly, during the COVID-19 pandemic we have witnessed an increasing shift from passive medicorobots (robots operated by humans) (Smith-Guerin, Nouaille, Vievres, & Poisson, 2008) to semi-independent robots with minimal human actuation (Kasina, Bahubalendruni, & Botcha, 2017).

Acceleration of medicorobotic capabilities

There is little doubt that COVID-19 will provide the stimulus for investing and augmenting the current capabilities of medicorobots. The globe is undergoing collective trauma that will not be easily erased if and when this current pandemic subsides. We forecast that governments will move towards expanding and improving medicorobots in preparation for future pandemics when they occur. China's quick mobilization of medicorobots has already been taken note by other nations.

Current psychomotor capabilities of medicorobots are primitive in relation to humans. Medicorobots lack the fine-tuning motor skills of humans. This is a major reason why Fox (2018) believes that resources should be directed to in-the-body enhancement technologies that are more efficient than building robots. Point taken. At present, even though complex decision making is beyond the reach of existing medicorobots, artificial intelligence designers are striving to make medicorobots responsive to human affectivity (Breazeal, 2003). Such tasks would have to use artificial intelligence methods, that, albeit, capable of processing vast quantities of information, rely on binary codes rather than on analog interactions of neurosecretions occurring in human brains. Complex decision making could theoretically be made by IN-WORLD medicorobots. This, however, would require robots to be able to understand patients' emotions,motivations, and sociocultural environments (Sequeira, 2018).

A further development in medicorobot competencies which have been accelerated by the COVID-19 pandemic will be the expansion of virtual avatar robot system capabilities that are presently being designed in Japan. Well known artificial intelligence designer Hiroshi Ishiguro created a small humanoid robot called Telenoid that embodies paedomorphic features, with miniscule arms and lacking legs. Telenoid has inbuilt sensors through which a remote staff member can talk through. The staffer's voice exits Telenoid's mouth simulating the action of talking. Telenoid has successfully been used in Japanese nursing homes for dementia patients (Lufkin, 2020).

We foresee that future Telenoid robots will also have inbuilt visual sensors which will enable remote individuals to talk and see the receiver, as well as, embedded microphones in the robot's ears for remote parties to hear the recipient. Inclusion of larger moveable arms which can be remotely controlled to touch the receiver in different ways, will enhance emotional involvement between individuals. Additionally, future 'chameleon' Telenoid models could be covered with living tissue or synthetic skin which could change skin colour and facial features, as well as, a trunk simulating respiration. The prospect that humans can behave in an empathetic way towards inanimate mechanisms cannot be dismissed (Rosenthal-Von Der Pütten, Schulte, Eimler, Sobieraj, Hoffmann, Maderwald, … Krämer, 2014). Do robots trigger a similar kind of empathetic response in humans which has been previously directed towards sentient beings? The Swiss psychologist Jean Piaget noted that toddlers pass through an "animalistic stage" in which they imbue the non-sentient world with emotion (Glausiusz, 2015). Throughout history humans have had a desire to connect with both animate and inanimate worlds. This desire for connectedness is now evolving by interacting with artificial intelligence (Sequeira, 2018).Modified versions of Telenoid robots could be used in many sectors and circumstances (i.e. quarantining in order to reduce isolation, social interaction among the elderly and hospital patients, companionship, learning) (Lathan, et al., 2001; Wada, Shibata, Saito, & Tanie, 2002; Kidd, Taggart, & Turkle, 2006; Wada, Shibata, Musha, & Kimura, 2008). Based on our current use of medicorobots, in the future IN-WORLD based Telenoids will further challenge our ideas of human embodiment and its interaction with artificial intelligence.

Conclusion

Although COVID-19 pandemic has been an unprecedented global crisis it has challenged ourold fashioned perception of robots. From here onwards, medicorobots will become an established feature in hospitals due to their utility and ability to perform repeated and life saving tasks as we have witnessed in Chinese hospitals. While some theorists are concerned with the humanization of robots (Robert, 2017), the COVID-19 pandemic has identified areas where robots and humans can beneficially interact. The last twenty years have been significant in developing functional medicorobots. Furthermore, the IN-WORLD model of current medicorobots may in the future facilitate a new generation of humanoid lookingrobots with the ability to perform facial emotional recognition and engage in emotional learning with humans. Such enhancements will optimise patient/robot interaction (Chellappa, Wilson, & Sirohey, 1995; Ogata, & Sugano, 2000). As history shows us, technology is often spurred during times of emergency. The age of modern pandemics has engendered a new chapter between human and machine.

References

Bateson, G. (1973). *Steps to an ecology of mind*. Oxford: Clarendon Press.

Bhatia, A. (2020 March 25). From Kerala, a robot to take care of coronavirus patients. Retrieved from https://indianexpress.com/article/technology/tech-news-technology/from-kerala-a-robot-to-take-care-of-coronavirus-patients-6329400/

Bloss, R. (2011). Mobile hospital robots cure numerous logistic needs. *Ind. Robot: Int. J., 38*, 567–571.

Breazeal, C. (2003). Emotion and sociable humanoid robots. *Int. J. Human-Computer Studies, 59*, 119–155.

Brooks, R. (1986a). Achieving artificial intelligence through building robots. Technical Report Memo 899. MIT AI lab.

Brooks, R. (1986b). A robust layered control system for a mobile robot. *IEEE Journal of Robotics and Automation, 2*, 14-23.

Chellappa, R., Wilson, C. L., & Sirohey, S. (1995). Human and machine recognition of faces: A survey. *IEEE Proceedings, 83*(5), 705–740.

Chen, T. L., & Kemp, C. C. (2011). A direct physical interface for navigation and positioning of a robotic nursing assistant. *Adv. Robot., 25*, 605–627.

Dahl, T. S., & Kamel, M. N. (2014). Robots in health and social care: A complementary technology to home care and telehealthcare? *Robotics 3*(1), 1-21.

Duffy, B. R., & Joue, G. (2000). Intelligent robots: the question of embodiment. Department of Computer Science, University College Dublin, Ireland. Retrieved from file:///C:/Users/Home/Downloads/Intelligent_robots_The_question_of_embodiment%20(2).pdf

Evans, J. M. (1994). HelpMate: an autonomous mobile robot courier for hospitals. Proceedings of the IEEE/RSJ/GI International Conference on Intelligent Robots and Systems (IROS'94), 3,1695–1700.

Foucault, M. (2003). The Birth of the Clinic: An Archaeology of Medical Perception. Routledge.

Frennert, S. A., Forsberg, A., & Östlund, B. (2013). Elderly people's perceptions of a telehealthcare system: Relative advantage, compability, complexity and observability. *J. Technol. Hum. Serv.* (31), 218–237.

GCiS report. (2017). China Strategic Research. Retrieved from http://www.gcis.com.cn/11-lps/122-china-commercial-service-robots-market-research-report

Glausiusz, J. (2015, April 8). Empathy for inanimate objects. Retrieved from https://theamericanscholar.org/empathy-forinanimate-objects/#.W_ZB5JoRVPY

Haraway, D. (1991). *Simians, cyborgs and women: The reinvention of nature*. New York: Routledge.

Hornyak, T. (2020, March 18). Patients are provided with bracelets that are synced with the robotic systems. CNBC. Retrieved from https://www.cnbc.com/2020/03/18/how-china-is-using-robots-and-telemedicine-to-combat-the-coronavirus.html

Kasina, H., Bahubalendruni, M. V. A. R., & Botcha, R. (2017). Robots in Medicine: Past, Present and Future. *International Journal of Manufacturing, Materials, and Mechanical Engineering, 7*(4), 44-64.

Kidd, C. D., Taggart, W., & Turkle, S. (2006). A sociable robot to encourage social interaction among the elderly. *Proc. IEEE Int. Conf. Robotics and Automation, Orlando, FL.* Retrieved from DOI: 10.1109/ROBOT.2006.1642311

Lathan, C., Vice, J. M., Tracey, M., Plaisant, C., Druin, A., Edward, K., & Montemayor, J. (2001). Therapeutic play with a storytelling robot. *Conference On Human Factors in Computing Systems – Proceedings*, 27-28. DOI: 10.1145/634067.634088

Luke, T. W. (1997). At the end of nature: cyborgs, 'humachines', and environments in postmodernity. *Environment and Planning A, 29*, 1367-1380.

Lufkin, B. (2020, February 6). Japan is rolling out robots in nursing homes, offices and schools as its population ages and workforce shrinks. What can it teach other countries facing the same problems? Retrieved from https://www.bbc.com/worklife/article/20200205-what-the-world-can-learn-from-japans-robots

Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and cognition – the realization of the living*. Dordecht, Holland, D. Reidel Publishing.

Murphy, R. R., Adams, J., & Gandudi, V. G. M. (2020, April 22). Robots are playing many roles in the coronavirus crisis – and offering lessons for future disasters. The Conversation. Retrieved from https://theconversation.com/robots-are-playing-many-roles-in-the-coronavirus-crisis-and-offering-lessons-for-future-disasters-135527

Ogata, T., & Sugano, S. (2000). Emotional communication robot: WAMOEBA-2R emotion model and evaluation experiments. *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).* Retrieved April 2, 2020, from https://www.cs.cmu.edu/~cga/humanoids/wamoeba.pdf

Oña, E. D., Garcia-Haro, J. M., Jardón, A., & Balaguer, C. (2019). Robotics in health care: Perspectives of robot-aided interventions in clinical practice for rehabilitation of upper limbs. *Appl. Sci, 9*(13), 2586.

Robert, L. P. (2017). The growing problem of humanizing robots. *Int. Robot. Autom. J.,* 3, 43. Robotics, 3, 1-21.

Roderick, S., & Carignan, C. (2007). Designing safety-critical rehabilitation robots. In S.S. Kommu (Ed.), *Rehabilitation Robotics. Volume 1*. (pp.43-64). Vienna, Austria: Intech Education and Publishing.

Rosenthal-Von Der Pütten, A. M., Schulte, F. P., Eimler, S. C., Sobieraj, S., & Hoffmann, L., Maderwald, S., … Krämer, N. C. (2014). Investigations on empathy towards humans and robots using fMRI. *J. Comput. Hum. Behav.*, 33, 201–212.

Sequeira, J. S. (2018). Can social robots make societies more human? *Information, 9,* 295.

Smith-Guerin, N., Nouaille, L., Vievres, P., & Poisson, G. (2008). A medical robot kinematics design approach based on knowledge management. *Ind Robot., 35*(4), 316–323.

Sucher, J. F., Rob Todd, S., Jones, S. L., Throckmorton, T., Turner, K. L., & Moore, F. A. (2011). Robotic telepresence: A helpful adjunct that is viewed favorably by critically ill surgical patients. *Am. J. Surg.,* 202, 843–847.

Wada, K., Shibata, T., Musha, T., & Kimura, S. (2008). Robot therapy for elders affected by dementia. *IEEE Eng. Med. Biol. Mag., 27,* 53–60.

Wada, K., Shibata, T., Saito, T., & Tanie, K. (2002). Analysis of factors that bring mental effects to elderly people in robot assisted activity. *Proc. Int. Conf. Intelligent Robots and Systems, Lausanne, Switzerland.*

Yang, G., Nelson, B. J., Murphy, R. R., Choset, H., & Christensen, H. (2020). Combating COVID-19: The role of robotics in managing public health and infectious, diseases. *Science Robotics, 5*(40). DOI: 10.1126/scirobotics.abb5589